

Post-flight Aerothermal Analysis of the Stardust Sample Return Capsule

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The Stardust Sample Return Capsule (SRC) was launched in February 1999 on a mission to retrieve samples of interstellar dust from the tail of comet WILD-2. Stardust returned to Earth in January 2006 entering the atmosphere with a velocity of 12.6 km/s, the fastest Earth reentry and highest energy reentry of any artificial vehicle to date. Several optical instruments captured the reentry of Stardust through an observation campaign aboard the NASA DC-8 airborne observatory. Flow environments obtained from Computational Fluid Dynamics (CFD) solutions are loosely coupled with material response modeling to predict the surface temperature of Stardust throughout the reentry. The calculated surface temperatures are compared with the data from two spectral instruments onboard the airborne observatory, the Echelle camera and SLIT telescope. The gray body curves corresponding to the average and area-averaged surface temperatures predicted by the material response simulation have excellent agreement with the recorded Echelle data at lower altitudes. At these altitudes the CFD/material response coupling can predict the surface temperature to within 50 K. The CFD calculations alone overestimates surface temperatures because it does not take into account ablation, as the material response modeling does. At higher altitudes, the presence of paint on the heatshield could have contribution to the lower observed surface temperatures and explain the over-prediction by the simulated data, which does not account for the paint. The over-prediction of the simulated surface temperature coincides in time with the high emission intensity lines corresponding to paint products. The average surface temperatures resulting from the SLIT telescope analysis agree to within 5% with the average surface temperatures predicted by the material response. Surface temperature is one of the critical parameters used in the design of thermal protection systems since it is an indicator of material performance. The combined CFD/material response approach employed in the present analysis can thus be reliably used for future missions such as CEV Orion.